

## **Seasonality of Amazon Forests Not A Sun-Sensor Illusion**

Bi, Choi, Park, Knyazikhin & Myneni  
Speaker: Ranga B. Myneni  
Boston University  
rmyneni@bu.edu

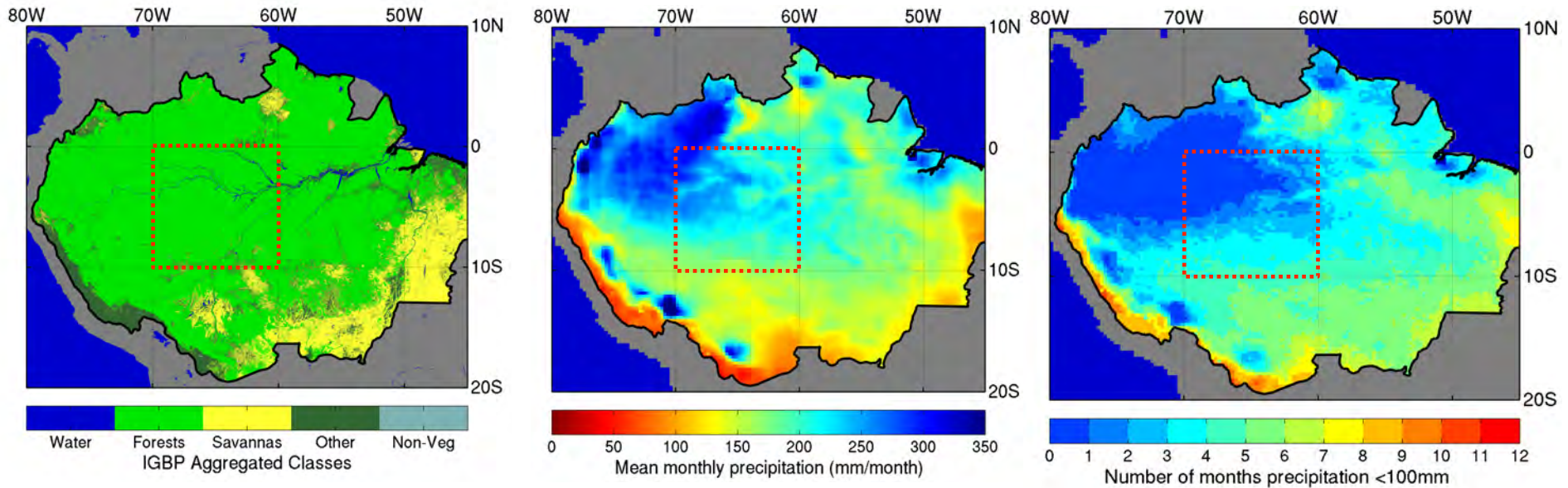
MODIS Science Team Meeting  
April 29 to May 1, 2014  
Columbia, MD

## Motivation

Morton et al. (2014):

- “Here we show that the apparent green up of Amazon forests in optical remote sensing data resulted from seasonal changes in near-infrared reflectance, **an artefact of variations in sun-sensor geometry**”
- “Previous green-up studies with MODIS EVI or LAI data **did not explicitly account** for changing viewing and illumination conditions”
- “Amazon forests **maintain consistent** canopy structure and greenness during the dry season”

## Study Area

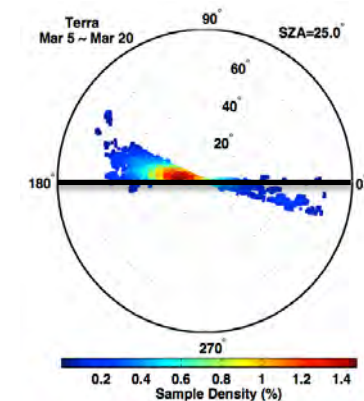
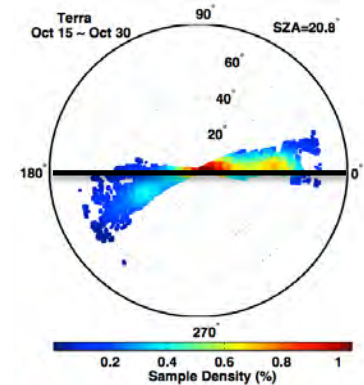
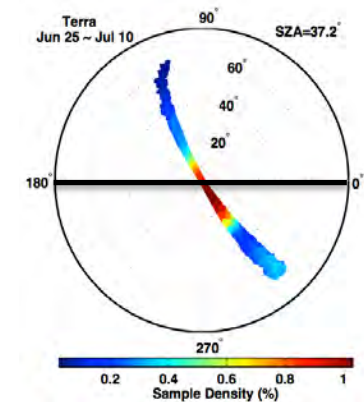
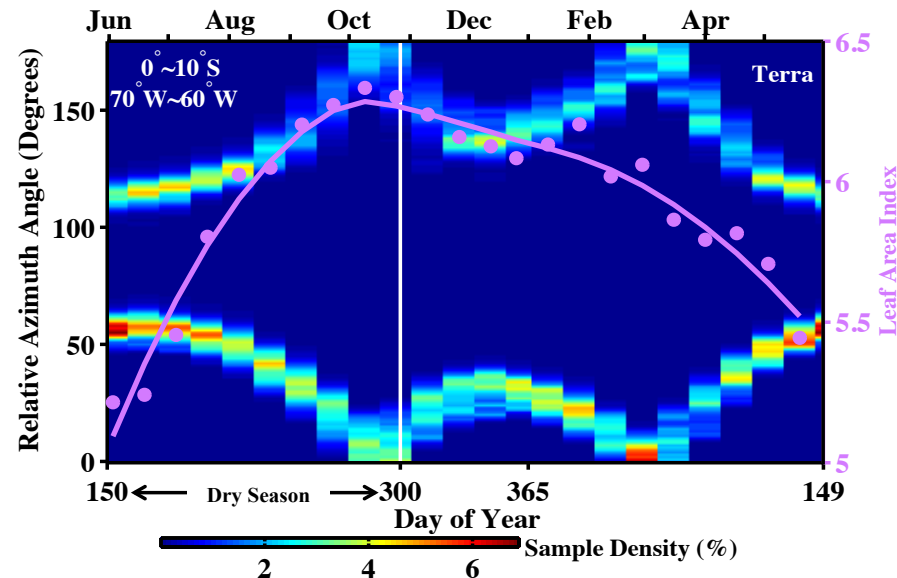


- Wet equatorial rainforests in a  $1200 \times 1200 \text{ km}^2$  area in the Amazon (MODIS Tile h11v09)
- Average annual rainfall over 2000 mm (TRMM data 1998 to 2012, excluding 2005 and 2010)
- Number of dry months (rainfall less than 100 mm) four or less
- One of two tiles studied by Morton et al.

- **MODIS LAI Analysis**

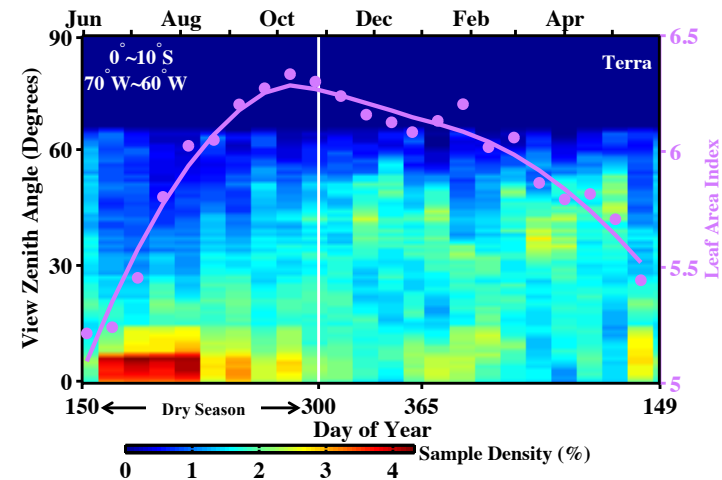
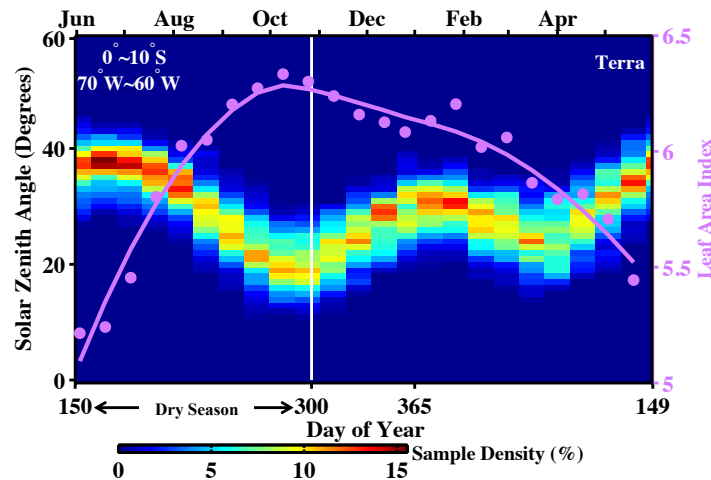
Terra MODIS Product from 7 Seasonal Cycles  
(June 2000 to March 2008, excluding June 2005 to May 2006)

## Seasonal Course of MODIS LAI Unrelated to Sun-Sensor Geometry



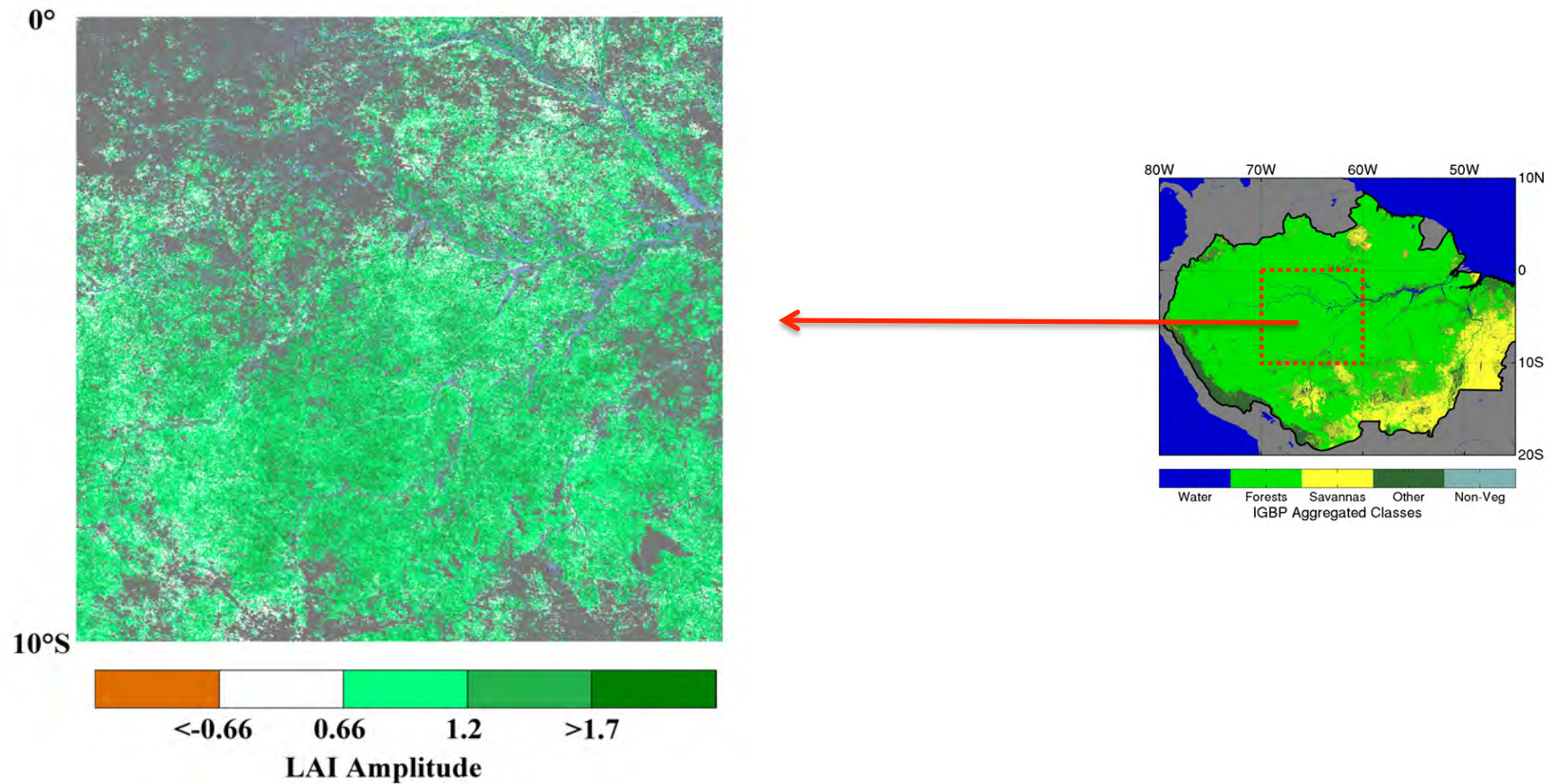
- LAI seasonality **does not track** the progression of MODIS sampling
  - off-principal plane in June
  - near-principal plane in October
  - off-principal plane in December
  - near-principal plane in March
- MODIS LAI algorithm explicitly **accounts** for sun-sensor geometry
- LAI seasonality suggests **net leaf flushing during the dry season** and **net leaf abscission during the long wet season**

## Seasonal Course of MODIS LAI Unrelated to Sun-Sensor Geometry



- LAI seasonality **unrelated** to seasonal course of solar zenith angle
- LAI seasonality **not influenced** by view zenith angle variations as they do not vary systematically through the seasonal cycle

## LAI Seasonal Amplitude



**Significant LAI Seasonal Amplitude in nearly all pixels that consistently show dry season EVI greening**

- LAI Amplitude = (Sep to Nov Max LAI) - (May to Jun Min LAI)
- White Pixels: LAI Amplitude less than |0.66|
- White and Colored Pixels: Show EVI greening in at least 4 out of 7 seasonal cycles
- EVI Greening: Oct EVI greater than Jun EVI

## Conclusions: LAI Analysis

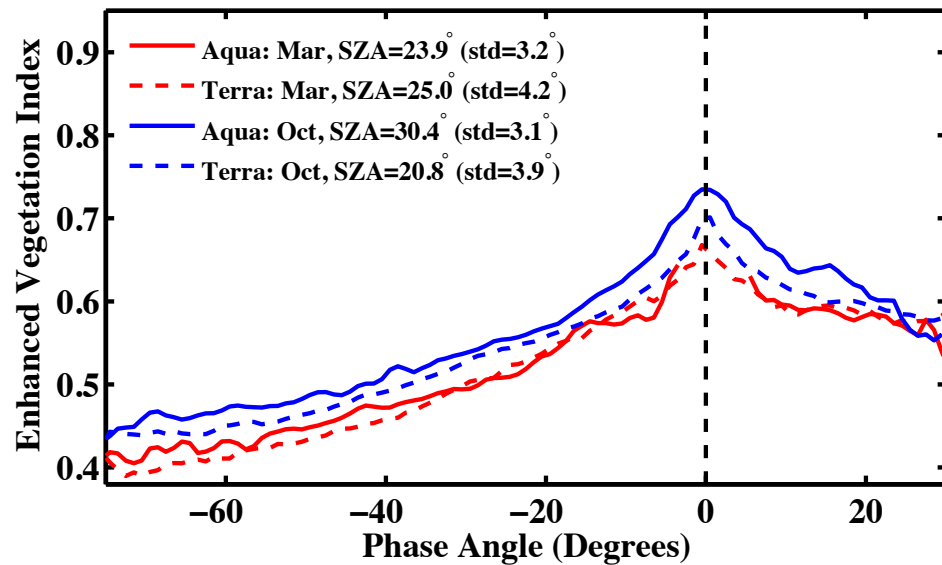
- MODIS LAI data are derived by explicitly accounting for changing viewing and illumination conditions
- Therefore, LAI data are free of sun-sensor geometry effects
- LAI seasonal cycle shows distinct net leaf flushing during the dry season and net leaf abscission during the wet season
- Wet equatorial Amazon forests do not maintain consistent canopy structure and greenness

- **MODIS EVI Analysis**

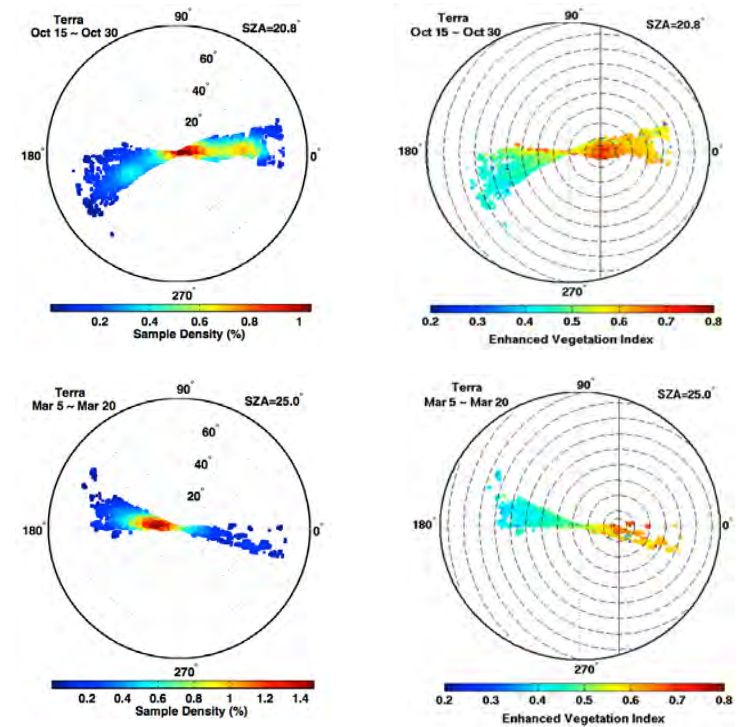
Terra MODIS Product from 7 Seasonal Cycles  
(June 2000 to March 2008, excluding June 2005 to May 2006)

Aqua MODIS Product from 4 Seasonal Cycles  
(June 2003 to March 2008, excluding June 2005 to May 2006)

## Net Leaf Abscission From Dry to Wet Season (MODIS)

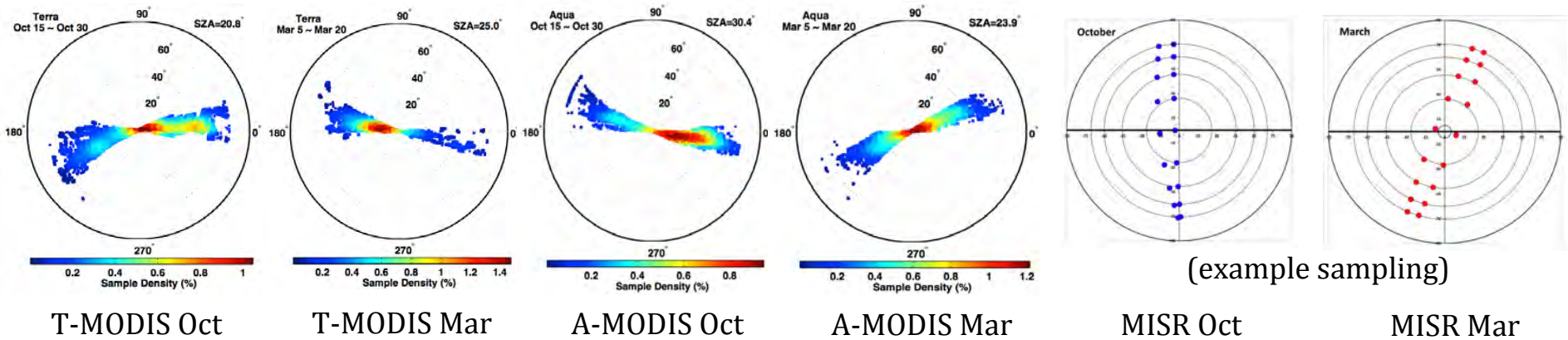
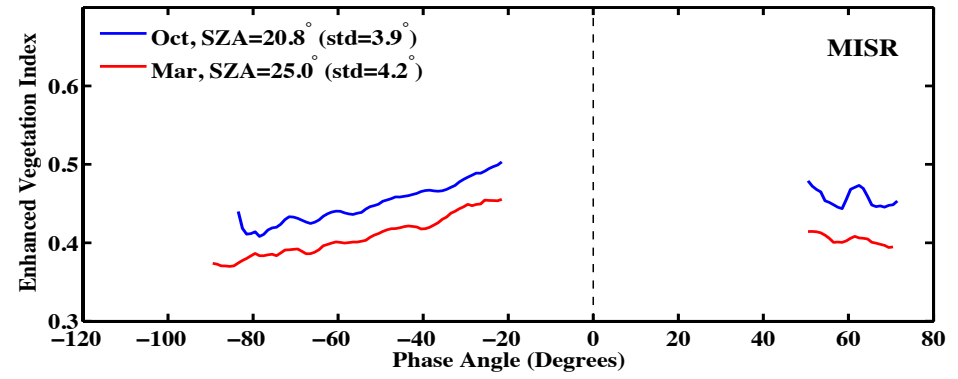
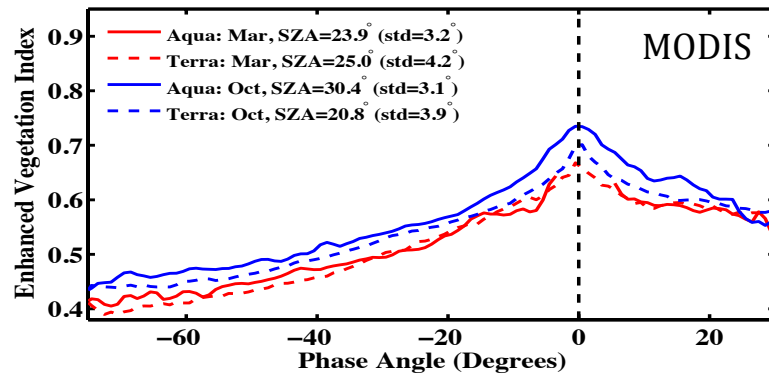


Phase Angle: Angle between sensor view and solar directions



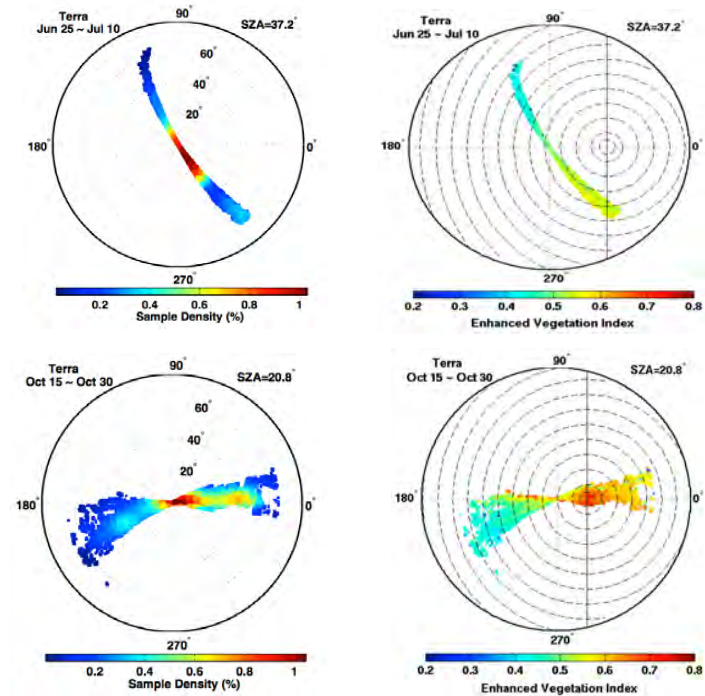
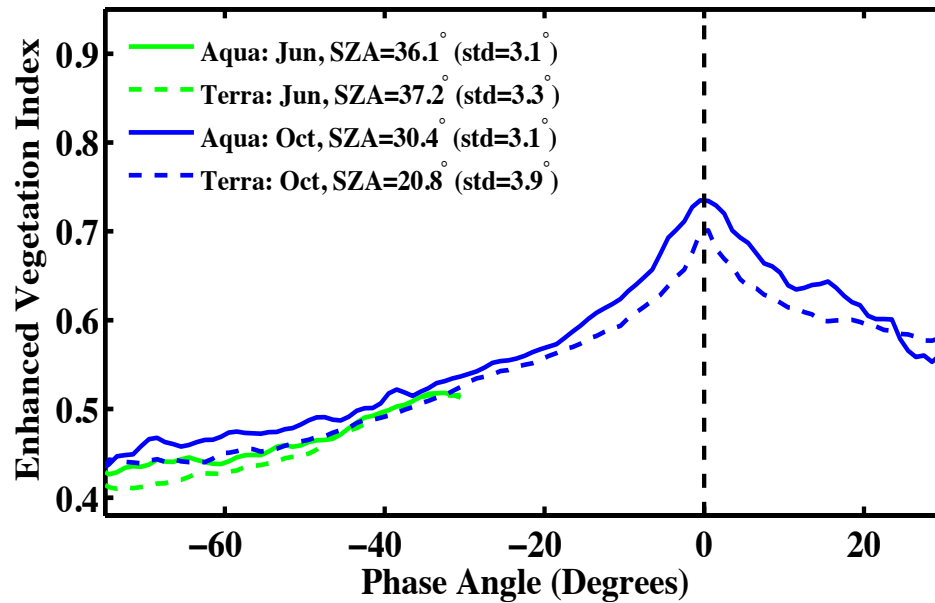
- October EVI **greater** than March EVI at the same phase angle
- **True** at all phase angles
- October to March EVI decrease indicates **net leaf abscission**
- Thus, there must be **net leaf flushing** during a 12-month cycle, else the result is a **leaf-less forest**

## Net Leaf Abscission From Dry to Wet Season (MODIS vs. MISR)



- MODIS and MISR data **congruent**
- October EVI **greater** than March EVI
- October to March EVI decrease indicates **net leaf abscission**

## Net Leaf Flushing During the Dry Season



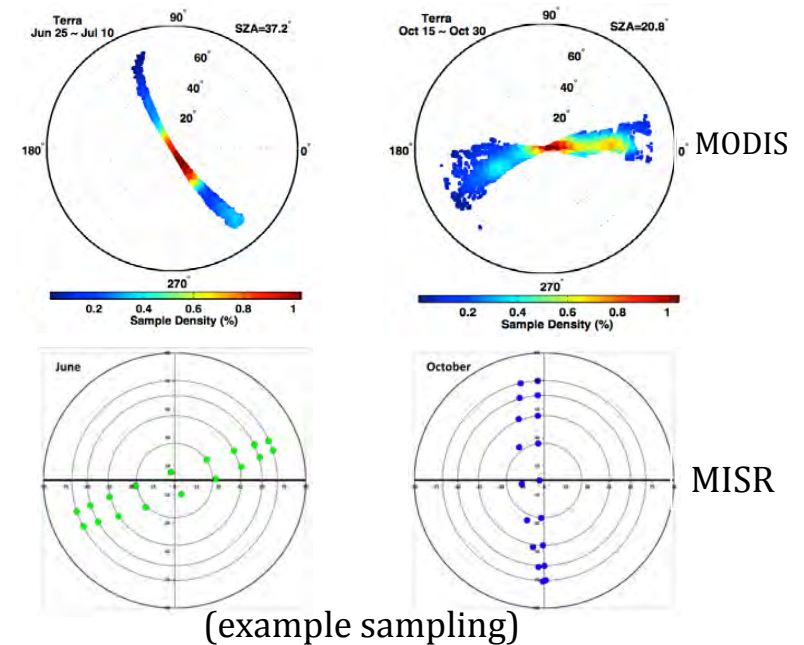
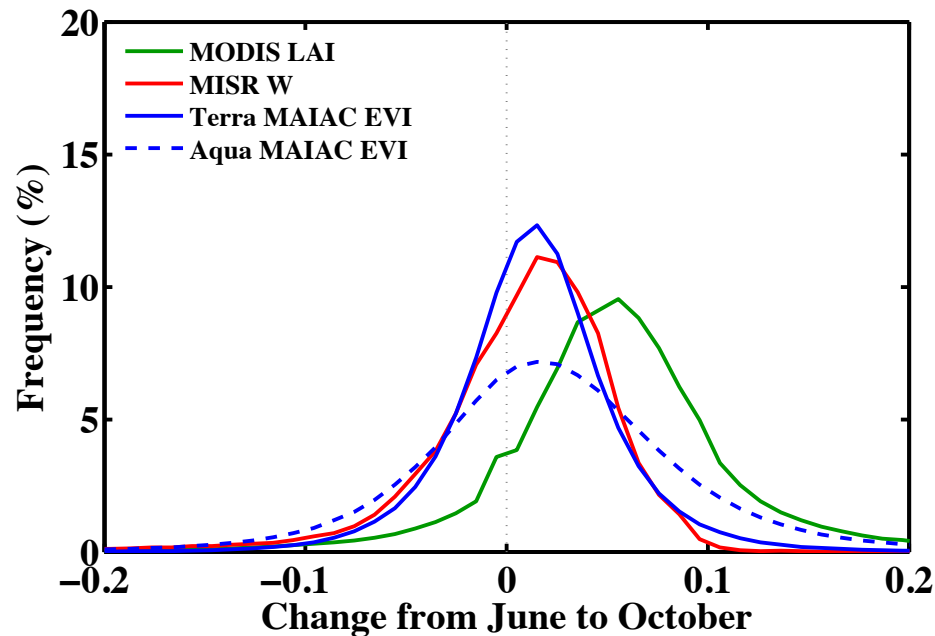
- October EVI **greater** than June EVI at phase angles for which comparable observations exist
- June to October EVI increase indicates **net leaf flushing**
- Thus, there must be **net leaf abscission** during a 12-month cycle, else the result is **infinite LAI**

## Conclusions: EVI Analysis

- Dry season greening and wet season browning are **not artefacts** of changing sun-sensor geometry
- Amazon forests **do not** maintain consistent canopy structure and greenness

- **Multi-Sensor & Multi-Product Analysis**

## Dry Season Greening



- Evidence for [dry season greening](#):
    - Terra & Aqua MODIS EVI (MAIAC) – Courtesy of A. Lyapustin
    - Terra MISR Near-infrared reflectance
    - Terra MODIS LAI (divided by 10)
- These data [are free](#) of sun-sensor geometry effects
- Note that MODIS and MISR sensors have [opposite sampling](#) in these months
  - If MODIS sampling results in [artificial greening](#), MISR sampling should result in [artificial browning](#)
  - But, in both cases [we see greening](#)

## Seasonality in Wet Equatorial Amazon Forests

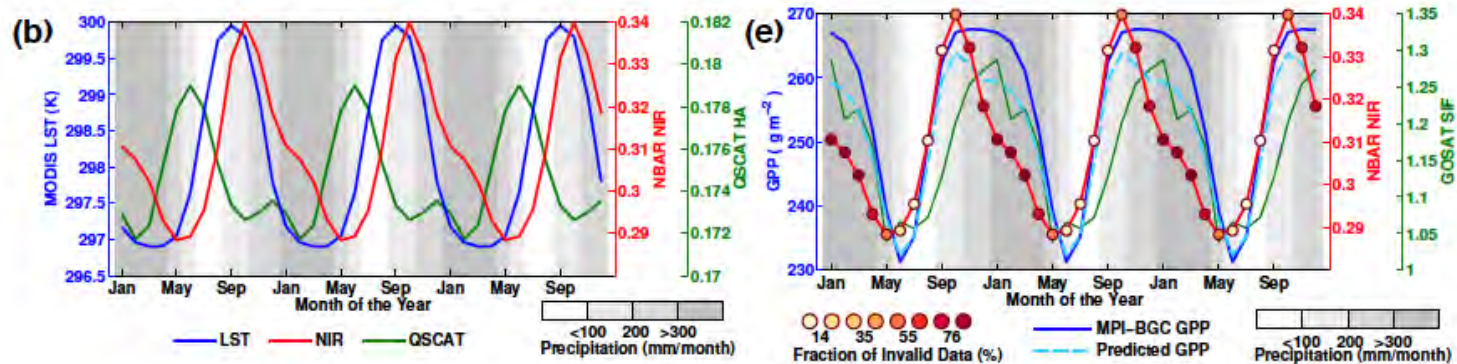


Figure courtesy of Xu and Saatchi

- Seasonality evidenced from [multiple](#) data types, sensors and platforms:
  - Terra MODIS Land Surface Temperature (LST)
  - Terra MODIS NBAR Near-Infrared Reflectance
  - QSCAT Backscatter
  - GOSAT Sun-Induced Chlorophyll Fluorescence
  - Gross Primary Production upscaled from global network of flux towers
- Results from this comprehensive analysis [concordant](#) with those presented here

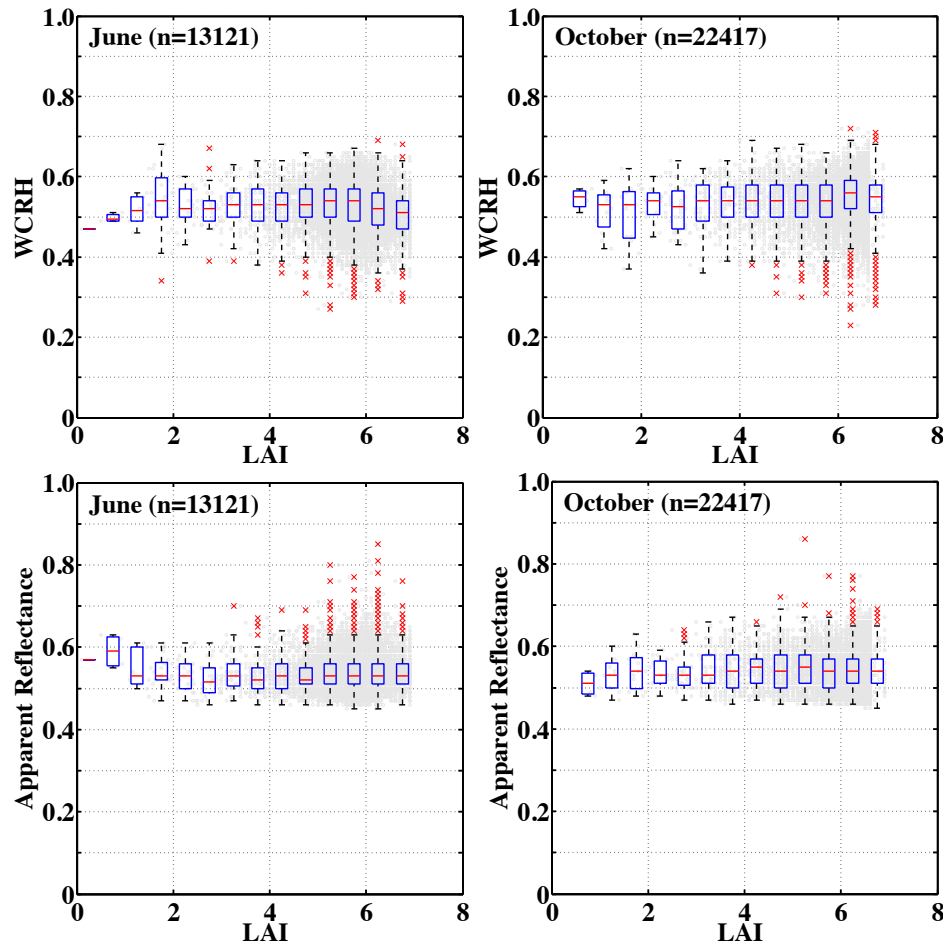
## Conclusions: Multi-Sensor & Multi-Product Analysis

- Various products/data from different instruments consistently show seasonality in wet equatorial Amazon forests\*

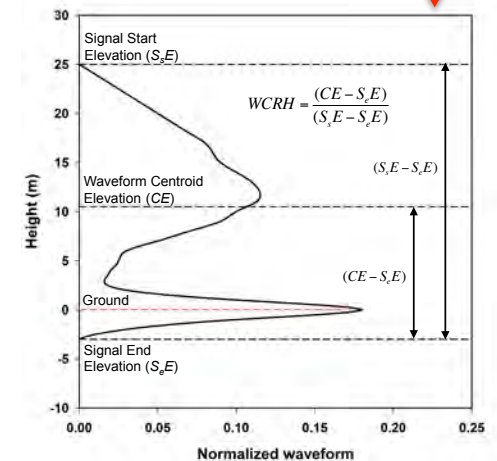
\*Vegetation Optical Depth (VOD) from AMSR (Courtesy of Jones, Kimball & Nemani)

- **GLAS Lidar Analysis**

## GLAS Metrics vs. MODIS LAI: Amazon Forests

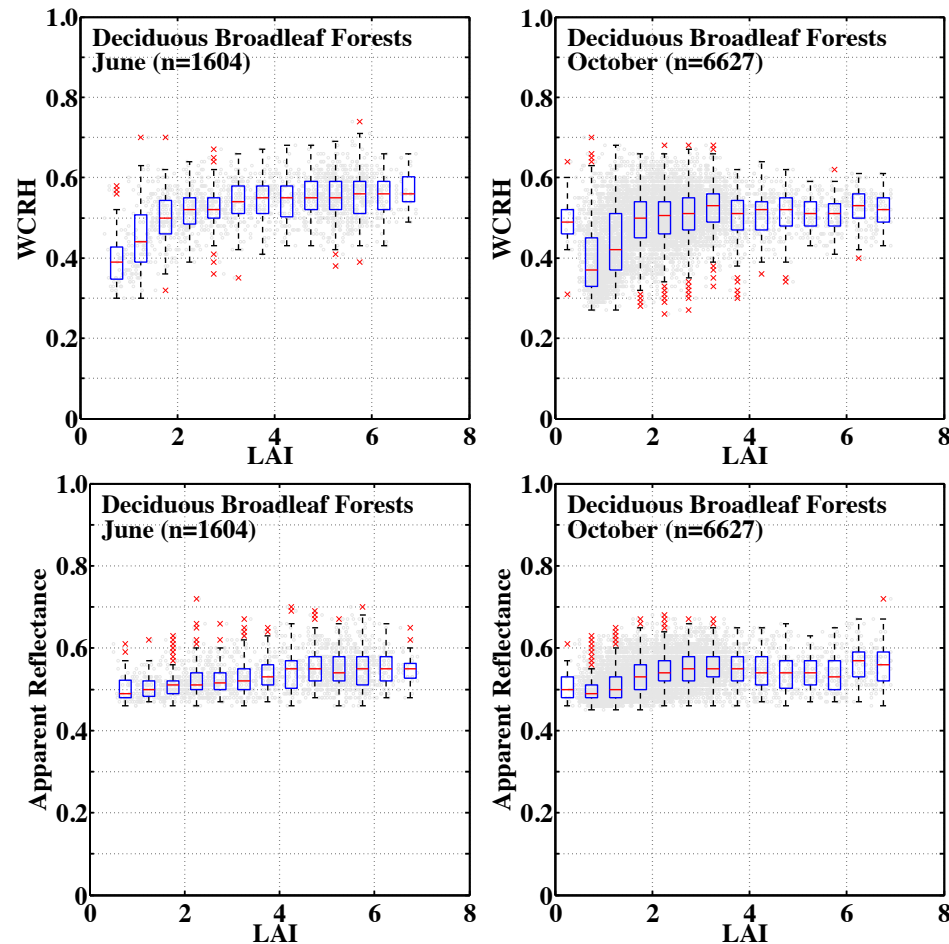


- June: 2005 and 2006
- October: 2004 and 2007
- By Campaign (no averaging over years)
- All GLAS data over Amazon Rainforests
- LAI 1km pixels with > 3 Lidar shots
- Two Metrics
  - WCRH (Centroid)
  - Apparent Reflectance (NIR)



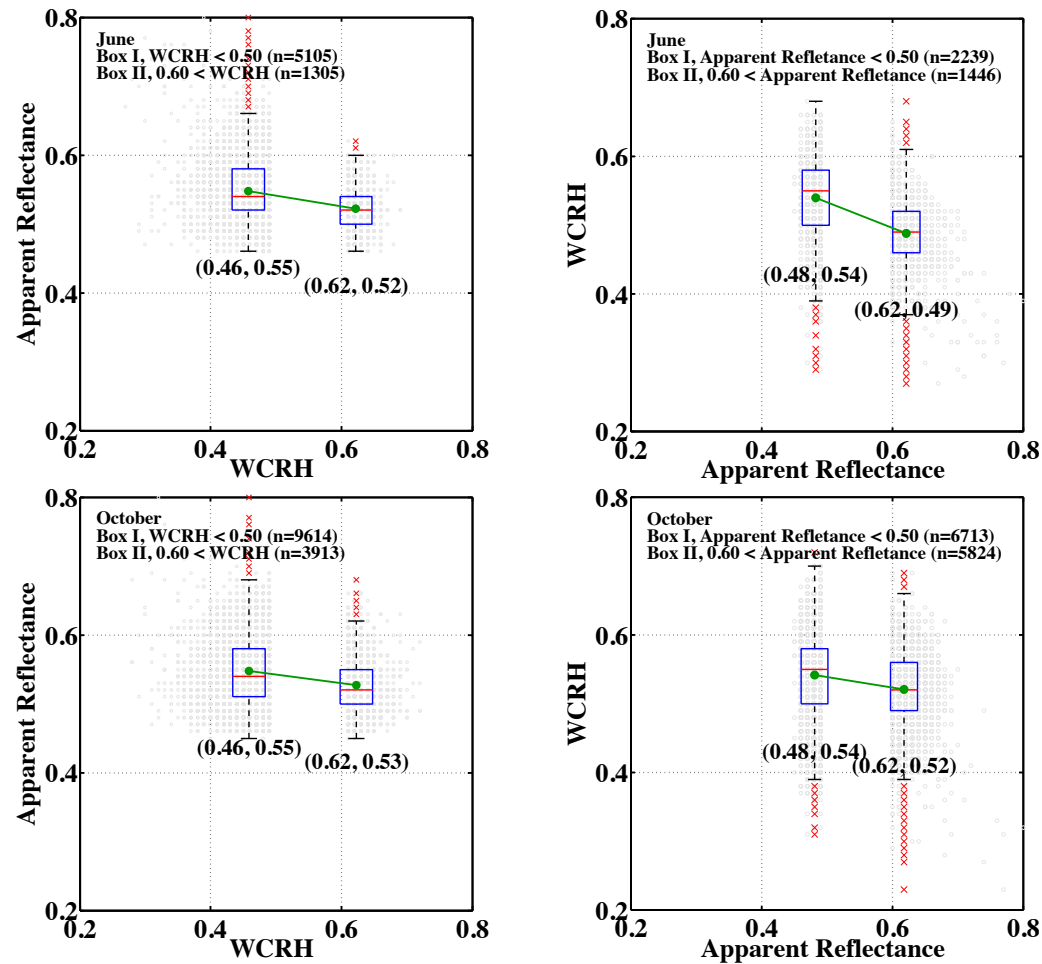
- No relationship between GLAS Metrics and MODIS LAI

## GLAS Metrics vs. MODIS LAI: Deciduous Forests



- GLAS Centroid **saturates** beyond LAI of 3
- GLAS Apparent NIR Reflectance **insensitive** to LAI

## Relationship Between GLAS Metrics: Amazon Forests



- Increase in Centroid **does not** correspond to increased reflectance
- Increase in reflectance **does not** correspond to increased Centroid

## Conclusions: GLAS Lidar Analysis

- GLAS metrics **not suitable** for determining LAI changes of Amazon forests due to **saturation**
- These forests maintain LAI greater than 5 during the entire seasonal cycle and exhibit a seasonal LAI variation of about 1
- The old adage “absence of evidence is not evidence of absence” applies here

## Overall Conclusions

- Wet equatorial Amazon forests **do not** maintain consistent structure and greenness
- They **exhibit** a distinct light driven seasonal cycle

